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NUCLEAR WASTE MANAGEMENT:
STORAGE AND DISPOSAL ASPECTS

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Nuclear Waste Management: Storage and Disposal Aspects ††

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ABSTRACT

Long-term disposal of nuclear wastes must resolve difficulties arising chiefly from the potential for contamination of the environment and the risk of misuse. Alternatives available for storage and disposal of wastes are examined in this overview paper. Guidelines and criteria which may govern in the development of methods of disposal are discussed.

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INTRODUCTION

Since the beginning of the nuclear industry thirty-five years ago, no final comprehensive plan has been established for the disposal of radioactive wastes from the nuclear weapons and commercial nuclear power programs. Certain of these wastes emit heightened levels of radioactivity for thousands of years. The hazard posed by the potential for release to the environment has commanded continuing attention.

It had been assumed that the solution could be easily achieved through isolation: burying the waste deep in geologic formations such as salt mines. Studies and tests continue on salt and potential alternatives.

The fuel value retained in spent fuel from power operations makes it worth considering reuse of the material. It was commonly assumed that spent fuel would be reprocessed. Reprocessing makes available plutonium which can be burned up as reactor fuel but has a potential for dangerous misuse by virtue of its toxicity and its potential in making atomic weapons. (The mix of plutonium isotopes from power reactor operation is far from optimum for weapons but is still problematical.)

In October 1977, the Federal Administration announced a policy of non-proliferation. Part of that policy deferred indefinitely the reprocessing of spent fuel from commercial power plant reactors. The Department of Energy announced it would take title to spent fuel facilities from utilities on payment of one-time storage fees. Policy decisions on the long-term disposal form and method have not been made, pending further study of the alternatives and the evolution of political consensus.

The technical sequence for disposal would fit into the general outline shown in Figure 1. Alternative waste forms for disposal of either spent fuel[1] or reprocessed high level waste[2] (HLW) are listed in Figure 2.

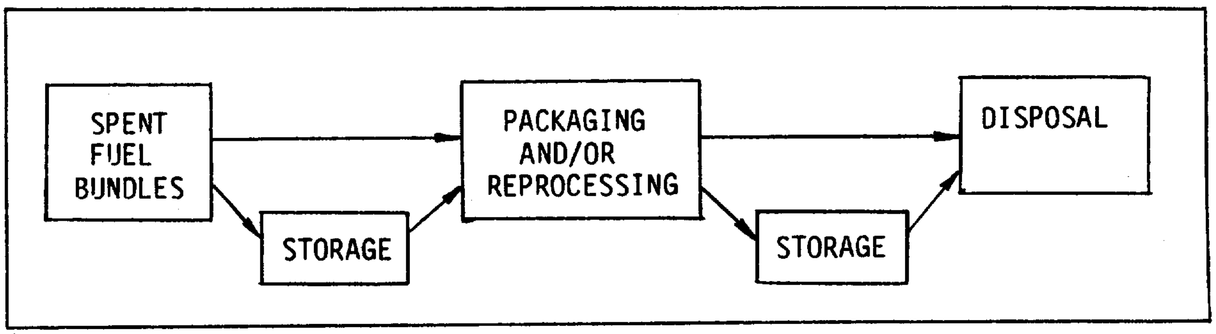

FIGURE 1. Storage and disposal sequence.

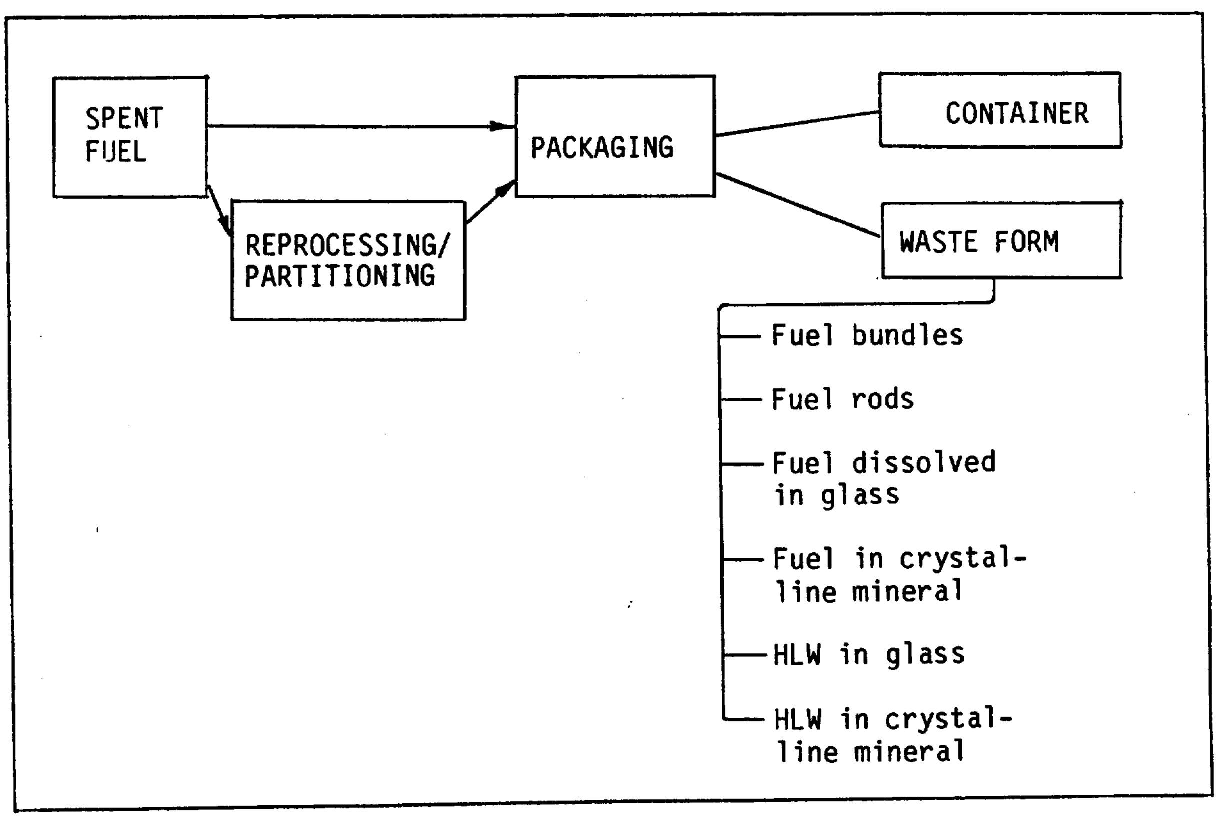

FIGURE 2. Waste form alternatives.

STORAGE

Near-Surface Storage

Waste storage alternatives[2,3] are outlined in Figure 3.

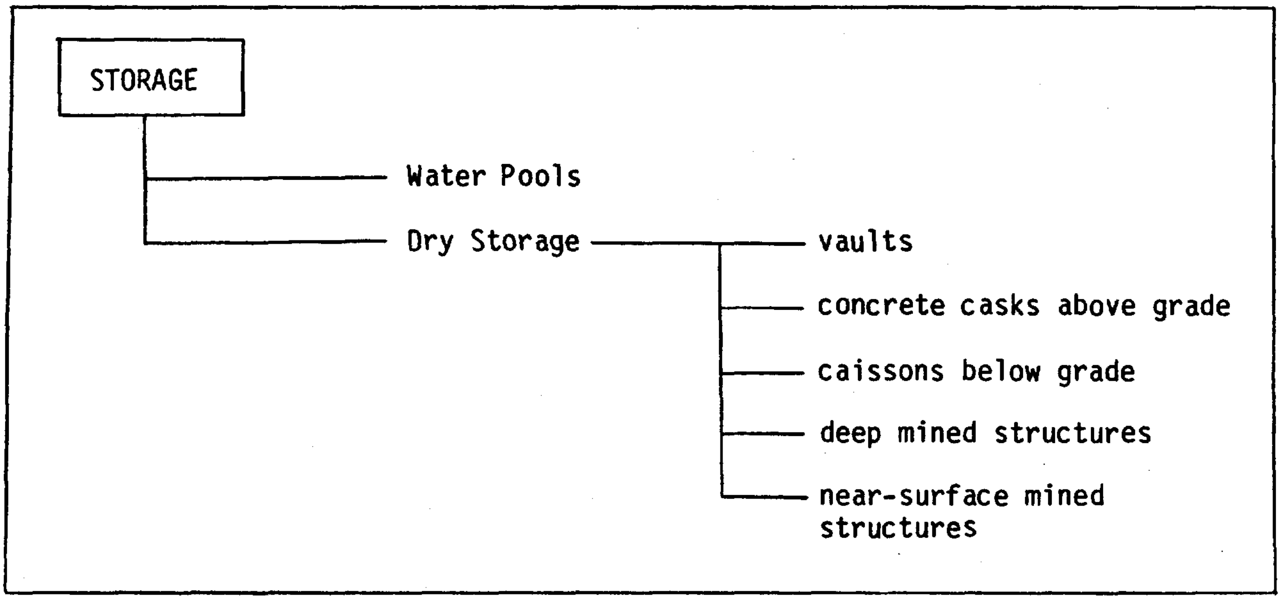

FIGURE 3. Storage alternatives.

The NRC has proposed criteria for self-contained spent fuel storage installations.[4] The NRC approach relies on engineered structures.

The benefits of this approach are:

1) Use is made of available technology.

2) Surveillance is possible, for purposes of detecting incipient releases or verifying predicted performance.

3) Materials are accessible for later placement in more permanent media as these become available.

LONG-TERM DISPOSAL ALTERNATIVES

The permanent disposal of the waste from spent nuclear fuel is required so that present and future generations are not harmed by it. The disposal might be done by one of several logical alternative methods: transformation into something less harmful (e.g. shorter half-lives) or isolation from the human environment, until natural decay transforms it into stable elements. (See Figures 4 and 5.) This paper discusses isolation.

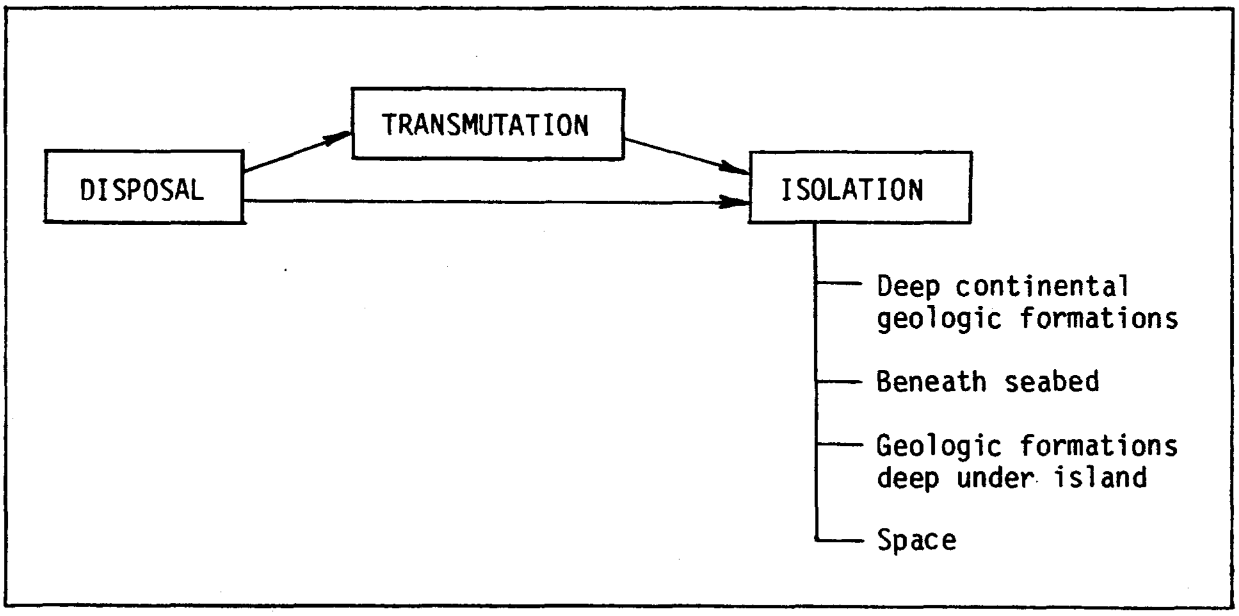

FIGURE 4. Disposal alternatives

The various alternatives' scope and status have been surveyed by the Energy Research and Development Administration (ERDA)[3,5] and more recently by the IRG[6,7] (Federal Interagency Review Group). An intensive study of the plausible alternatives is not only prudent before putting the best course into effect, but it is required by NEPA (the National Environmental Policy Act).

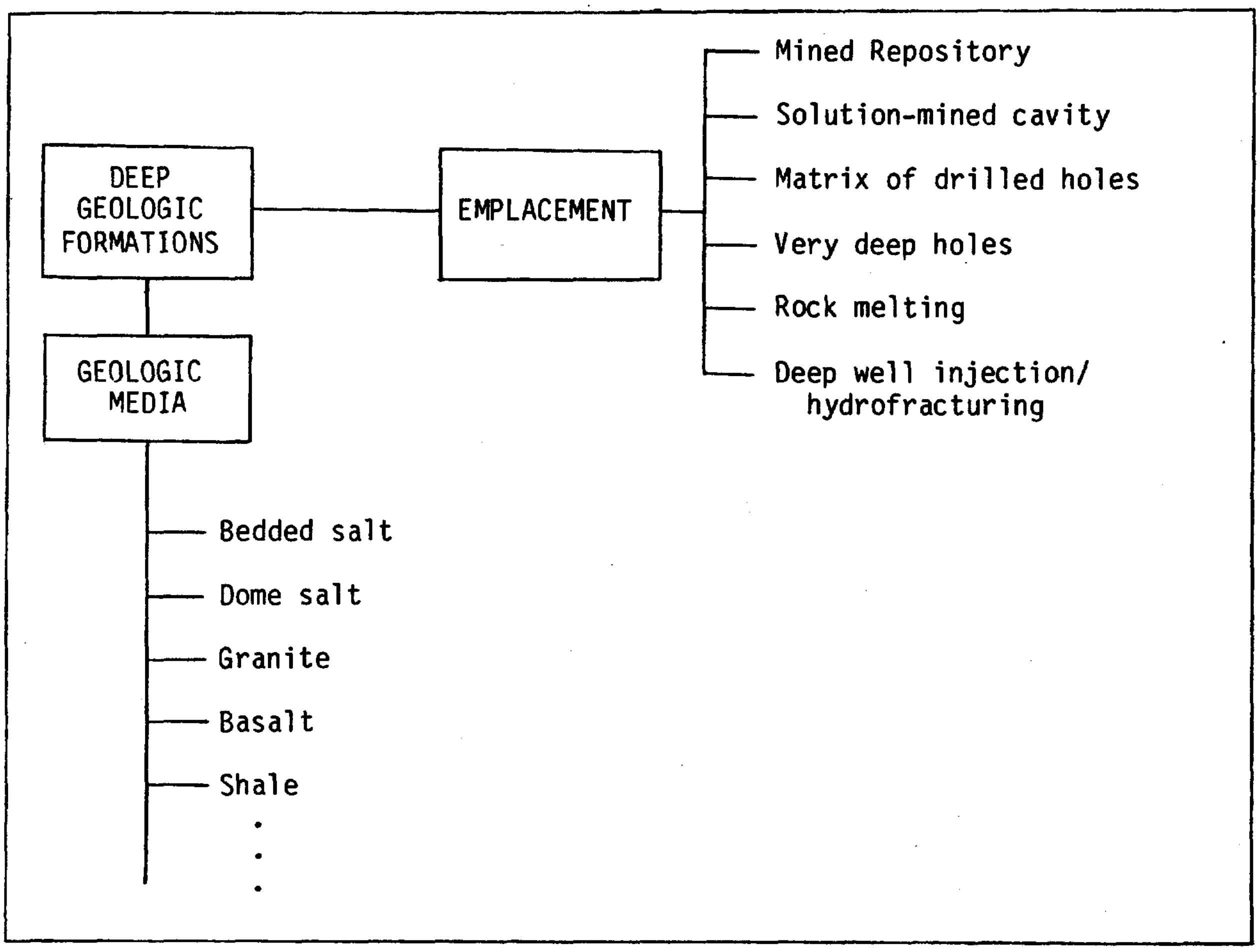

FIGURE 5. Disposal alternatives using deep continental geologic formations.

Some of these options have been the subject of extensive research and development, some would require substantial future research and some are still speculative at present.

Isolation could be achieved by a remote location: deep underground, on or under the seabed, or in space. Waste packaging and emplacement would be designed to enhance isolation. The isolation should be maintained at least until the waste has decayed to essentially innocuous levels. (What this means more specifically is still an open topic in criteria development.)

Unconsolidated materials have also been considered for isolation. Dilution and encapsulation in a geochemically stable material are first involved. Migration of the wastes so stored is a major consideration.

Isolation in a Mined Repository

The radioactive wastes are isolated in underground rock formations. Storage space is created using available mining technologies. Engineering techniques for mining emplacement and sealing, and scientific knowledge of the relevant processes in the post-sealing period, are close to sufficiency and need only modest advances along predictable lines.

The most intensive study has been on salt, since a National Academy of Sciences study[8] had recommended salt as most likely to be a safe medium. The U.S. studies in salt have included its geologic environments, geotechnical properties, thermal and chemical interactions with the waste, and several cycles of repository design. One produced a generic design.[9] More recently, the government has sponsored two designs by architect-engineering firms, one a design for disposal of spent nuclear fuel in bedded salt[10] and one for high level waste in dome salt.[11]

Recent doubters of the acceptability of salt include the U.S.S.R., and our own U. S. Geological Survey. Recently, because of desires to broaden the options technically and geographically, and with an eye toward NEPA requirements, the IRG recommended[6] and the Administration directed (February 12, 1980) that studies and development in other rock media be intensified. Several geologic media are being considered for the mined repository approach, including bedded salt, dome salt, granite, basalt, and shale.

The European community[12] is considering mined repositories in several rock media and is coordinating studies among its member countries: dome salt in W. Germany and the Netherlands, granite in Sweden, Great Britain and France, and clay in Belgium.

The design of a repository must consider not only operational safety but also the long-term future containment of the waste. This is discussed below under criteria.

Liquid High Level Wastes Fused Into Rock

Highly radioactive waste could be pumped into a deep cavity in an impermeable geologic formation. Heat from the radioactive waste would melt the adjacent rock and the radioactive material would ultimately become an integral part of the rock.

This option looks plausible but needs further development in engineering and in knowledge of rock mechanics and in waste heat-rock interaction at those depths.

Isolation in Deep Ocean Sediments

Ocean sediments which are thick, stable and accumulated over millions of years are in a process of becoming sedimentary rock. Waste could be implanted deep in these layers and the sediments deposited on top would provide additional security for its continued isolation.

Concentrated isolation would require further research into canister design and emplacement methods, geochemistry of the bottom mud environment and biology of the deep sea and sea floor. Several countries, including Great Britain,[13] are pursuing long-term research on this option. For low level non-transuranic waste, a quite different problem, seabed disposal guidelines have been developed by the OECD[14] for its member countries.

GUIDELINES AND CRITERIA

All stages of the waste disposal process must be subjected to scrutiny: handling at the source, removal and transportation, processing, storage, and ultimate disposal.

Conditions considered should include normal operation and events which are reasonably foreseeable. These would include:

normal conditions: dead and live loads, temperature;

natural phenomena: flood, earthquake,[15] tornado, wind;

accidental occurrences during operation: handling errors, transportation accidents;

failures in materials and engineered equipment: geologic media, packaging, receiving structures, safeguard and monitoring equipment;

criminal and subversive acts: theft, sabotage, terrorism.

Applied to all of these conditions should be an evaluation of the hazard to populations and to the environment of a radiation release.

Layout and operational plans must also be designed to enhance the long-term future performance of the repository and geologic surroundings as a waste isolation system. Thus borehole and shaft integrity and sealing must be considered, as must possible rock or salt fracturing due to creep into the mined openings or due to waste thermal effects after backfill and closure. Geochemical stability or compatibility of the waste, backfill and host rock must also be considered.

The degree of isolation from the human environment and the relevant time scales are questions of criteria development being led by the Environmental Protection Agency (EPA). The design and performance criteria of components of the waste isolation systems are the subject of NRC standards development. These efforts involve public workshops[16] as well as the publication of studies and draft criteria. The EPA has published thoughts on guiding principles,[17] but to date has not published draft standards with specific numerical limits for the human environment. The NRC has published proposed procedural regulations and draft technical requirements for engineered and geologic components of the waste isolation system.[18,19]

Regulatory requirements should make maximum use of existing codes and standards. Supplementary design criteria and radiation exposure limits should be provided for new environments and needs not covered in the present framework of standards.

SUMMARY

It is important that reliable methods be developed for storing and disposing of nuclear wastes.

Near-surface storage is an interim measure, relying on storage in engineered structures. Higher accessibility provides the opportunity for surveillance to detect leakage, and to take corrective action. It also provides the opportunity for later repackaging of materials for permanent storage when an acceptable procedure becomes available, and the opportunity for reprocessing, if a properly safeguarded approach becomes available. Near-surface storage has the disadvantage that the same accessibility offers a possibly greater opportunity for misuse of the radioactive material.

The difficulties associated with long-term waste disposal are related to the potential environmental hazard, to the need for confidence in the long-term safe functioning of the disposal procedure, and to the need to assure that material will not be misused.

Long-term storage in land formations or in deep ocean sediments are permanent measures, characterized by remote isolation in geologic media. The problems with these schemes are tied to uncertainties in the behavior of materials under the physical conditions over a very long period of time. The remote disposal schemes do not offer the opportunity for corrective action if anything were to go wrong.

Research and development to find permanent measures for the disposal of wastes should be pursued. Several solutions are presently unavailable because of the interim government policy that no reprocessing be done. In this area, some new alternatives may develop which, in combination with reprocessing, could provide good solutions to the radioactive waste problem.

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